Temporal Change in Density and Size Structure of the Sea Cucumber Polycheira rufescens Inhabiting the Intertidal Boulder Beach at Hatakejima Island, Tanabe Bay, Central Japan

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With Text-figures 1–4 and Tables 1–3

Abstract A field population study of a holothurian, *Polycheira rufescens*, conducted at an intertidal boulder beach of Hatakejima Island in Tanabe Bay, central Japan, revealed that the temporal change in density varied with site and the density tended to be positively correlated with the abundance of small boulders of 10–20 cm length. Size frequency distribution was uni-modal and the peak remained at a constant size class irrespective of the season, but shifted to a smaller size class in a winter month. Size structure was similar in spite of higher and lower tide levels. The number of individuals occurring under a boulder tended to increase with boulder size. The mean body size of individuals under small and large boulder was not different in most cases.

Introduction

Polycheira rufescens (Brandt, 1835) is a chiridotid holothurian inhabiting intertidal boulder beaches of the tropical and subtropical Indo-West Pacific region (Utinomi, 1971). Recently, ecological aspects of this species have been dealt with by Nishihira *et al* (1978) who described the distribution, relationship between several body size indices, and fecal contents. Sloan (1979) briefly reported its habitat condition, density and degree of stationary tendency. Tomari & Kubota (1989) studied the spawning activities and the phenomena of sex reversal. However, a temporal change of the population has not been described so far.

Since this species lives under boulders, conditions of boulders are assumed to be significant in their spatial distribution. The relation between the distribution of this species and the boulder conditions has only been addressed by Sloan (1979), who recorded the relationship between the abundance and boulder size.

In the present study, I investigated the temporal change in the density and the size structure of a *P. rufescens* population in relation to the intertidal height and boulder size of the habitat near the northern limit of distribution of this species.

Materials and Methods

The study area was an intertidal boulder beach on the west coast of Hatakejima Island in Tanabe

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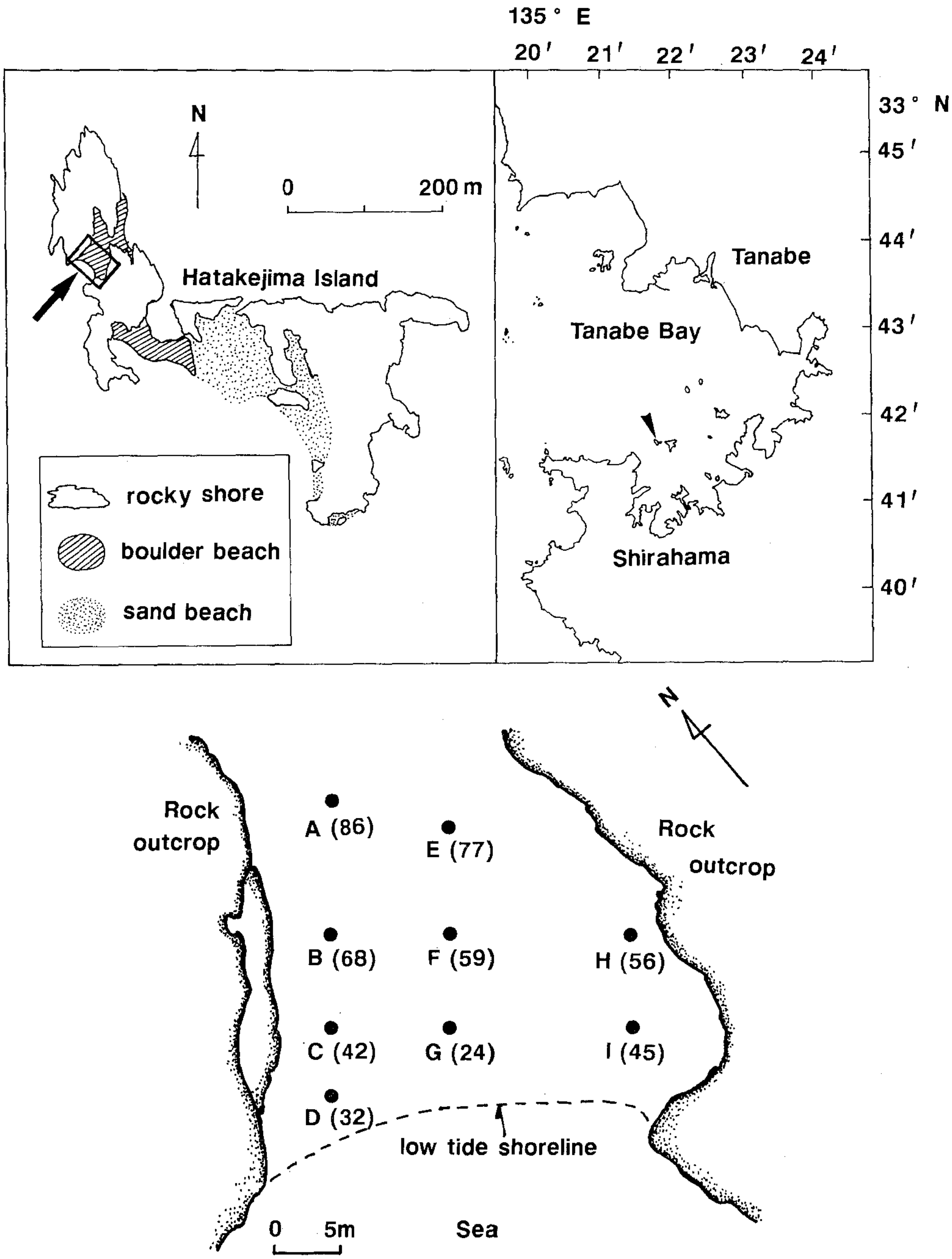

Fig. 1. Map showing 9 sampling sites (A-I) on an intertidal boulder beach of Hatakejima Island and location of the study area. Numerals in parentheses show the heights above datum line in cm.

Bay (33° 42'N, 135° 22'E), central Japan (Fig. 1). In this area (ca 900 m^2), 9 sampling sites (A-I) were selected, with A being highest and D being lowest (Fig. 1). Field samplings were carried out during spring low tide of May, August and November in 1987, February and May in 1988, and January in 1989. At each site, 4 quadrats, each measuring 1 m × 1 m, were set. Boulders larger than fist-size within the quadrat were measured for their maximum length and were overturned to examine the sea cucumbers underneath. When *P. rufescens* were found, the number and the body size of each individual were recorded for each boulder without killing them. Body size measurement was made by putting these live specimens in fresh water brought to the field. Since it is known that the minimum body length under fresh water has a good positive correlation with dry body weight (Nishihira *et al.*, 1978), the length of the most contracted body after immersion in the fresh water was measured with a ruler. Immediately after measurement, the specimens were released in their original sites. In addition, when other holothurian species were found in the quadrats, their numbers were also counted, but their body lengths were not measured.

Results and Discussion

Density

During this study, 4 species of sea cucumbers were observed and *P. rufescens* predominated among them (Table 1). *P. rufescens* occurred at all sampling sites, whereas the other 3 species, i.e. *Holothuria pardalis* Selenka, 1867, *Holothuria moebi* Ludwig, 1883, and *Afrocucumis africana* (Semper, 1869) were found at lower sites (C, D, F, G, H & I) located below 60 cm above datum line.

The abundance of *P. rufescens* showed a gradual decrease from May to November, 1987 and a gradual increase from November 1987 to May 1988 (Table 1), with a range in mean density from 3.4 to 9.3 per m^2. The maximum density (per m^2) of the species recorded at each survey ranged from 18 to 27. These are much smaller than the maximum value of $512/m^2$ and the mean value of $52.6/m^2$ reported by Nishihira *et al.* (1978) in Okinawa. However, it is similar to the maximum density ($20.7/m^2$) reported in Aldabra Atoll, Seychelles by Sloan (1979). Three other holothurian species were fewer in the late study period than in the early study period (Table 1).

Fig. 2 shows the temporal fluctuation in the density of *P. rufescens* at each sampling site, except site D where the density was extremely low. The density is smaller at E and B located at higher level as well as I and C at lower level. The pattern of fluctuation of the density varies with the study site. As seen in Fig. 2, the fluctuation in the density at each site appears to be correlated with the change in the proportion

Table 1. Total number of collected individuals of each holothurian species from all sampling sites at each survey.

	Holothuria pardalis	*Holothuria moebi*	*Afrocucumis africana*	*Polycheira rufescens*
1987 May	9	24	6	308
Aug.	15	13	0	203
Nov.	8	4	4	142
1988 Feb.	2	1	0	158
May	5	0	0	213
1989 Jan.	0	0	0	124

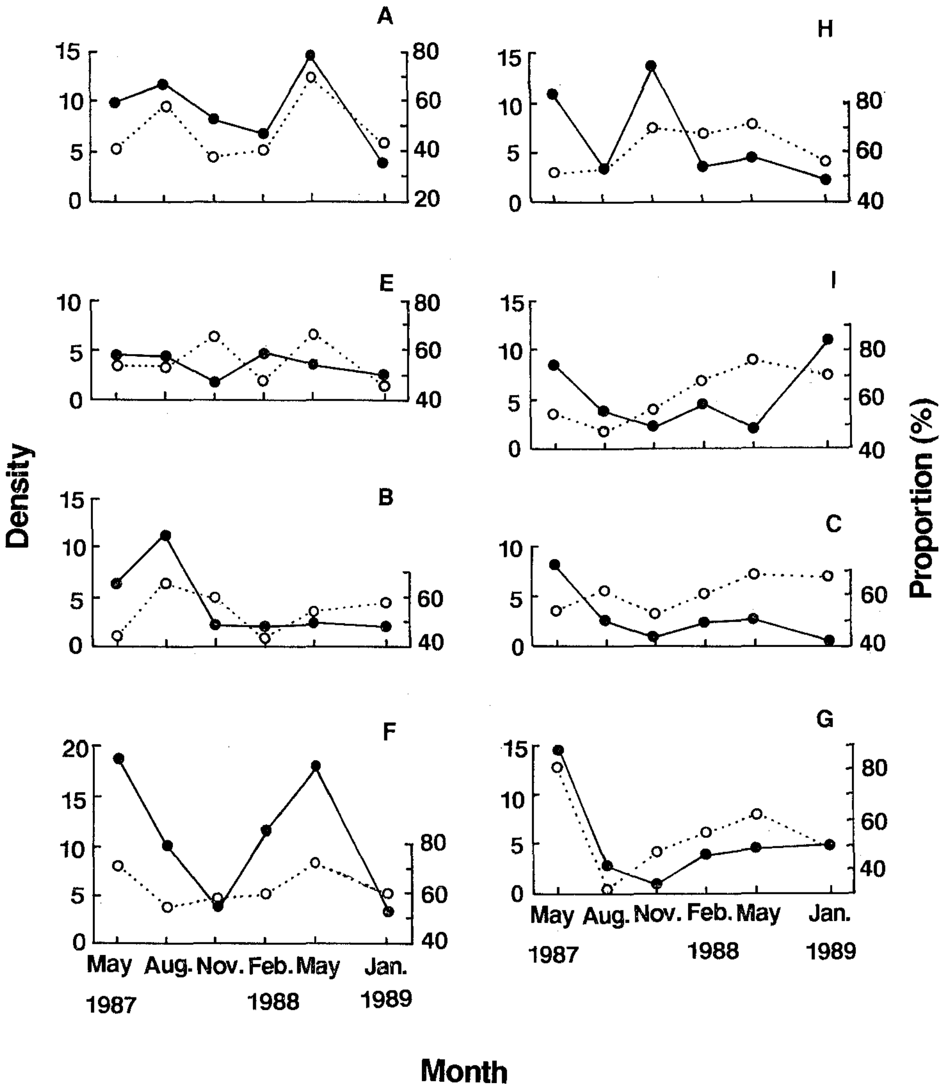

Fig. 2. Mean density (per m²) of *Polycheira rufescens* (solid circles) and proportion of small boulders (10–20 cm length) to all boulders above 10 cm length (open circles) at each sampling site of A-I from May 1987 through January 1989. The data at site D are not presented because of the extremely low density. Sites are arranged according to intertidal height from A (highest) to G (lowest). For the height above datum line at each site, see Fig. 1.

Table 2. The maximum and the mean number of *Polycheira rufescens* found under a boulder of three size classes (10–20 cm, 20–30 cm and 30–40 cm).

	10–20 cm	20–30 cm	30–40 cm
n	177	223	116
mean	1.3	1.8	2.6
max.	5	8	12

of the small boulders of 10–20 cm length within the quadrats, and a particularly significant positive correlation between them is exhibited at sites A ($P<0.02$), F ($P<0.05$) and G ($P<0.01$) (Kendall's rank correlation). Thus, *P. rufescens* tended to be more abundant at sites with more small boulders. Sloan (1979) noted that *P. rufescens* was strongly associated with the presence of gravel/sand substrate under boulders and its gut contents were composed of fine material. Nishihira *et al.* (1978) re-

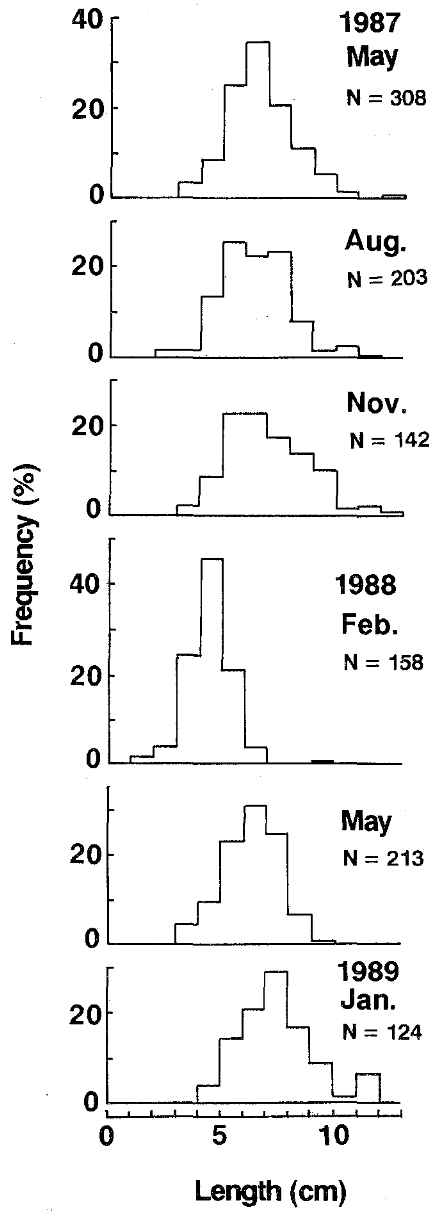

Fig. 3. Frequency distribution, as percentages, of body lengths of *Polycheira rufescens* collected from all sampling sites from May 1987 through January 1989.

ported that grain sizes of its feces did not exceed 4 mm in diameter. More small boulders would increase interstices, which might induce accumulation of fine sediment available as food. Many interstices under numerous small boulders would lead also to plenty of refuges or home places for *P. rufescens*.

Table 2 shows the maximum and the mean number of *P. rufescens* occurring under a boulder for each size class of boulders in all the surveys. The abundance per boulder tends to increase with boulder size, as reported by Sloan (1979).

Size structure

Fig. 3 shows the frequency distribution of body length of all individuals of *P. rufescens* collected at each survey. The histograms are unimodal, as observed in a population at Okinawa (Nishihira *et al.*, 1978). The peak remains constant at 6–7 cm length, except in February 1988, when the peak was at 4–5 cm length. This exception in February 1988 could be due to the following three reasons. The first is the death of larger individuals and the recruitment of newly-settled juveniles. The second is transverse fission, which is well known in intertidal holothurians (Emson & Wilkie, 1980). Harriott (1982) reported that the fission rate in *Holothuria atra* ranged from 6 to 70% of individuals examined during a year, and Emson & Mlade-

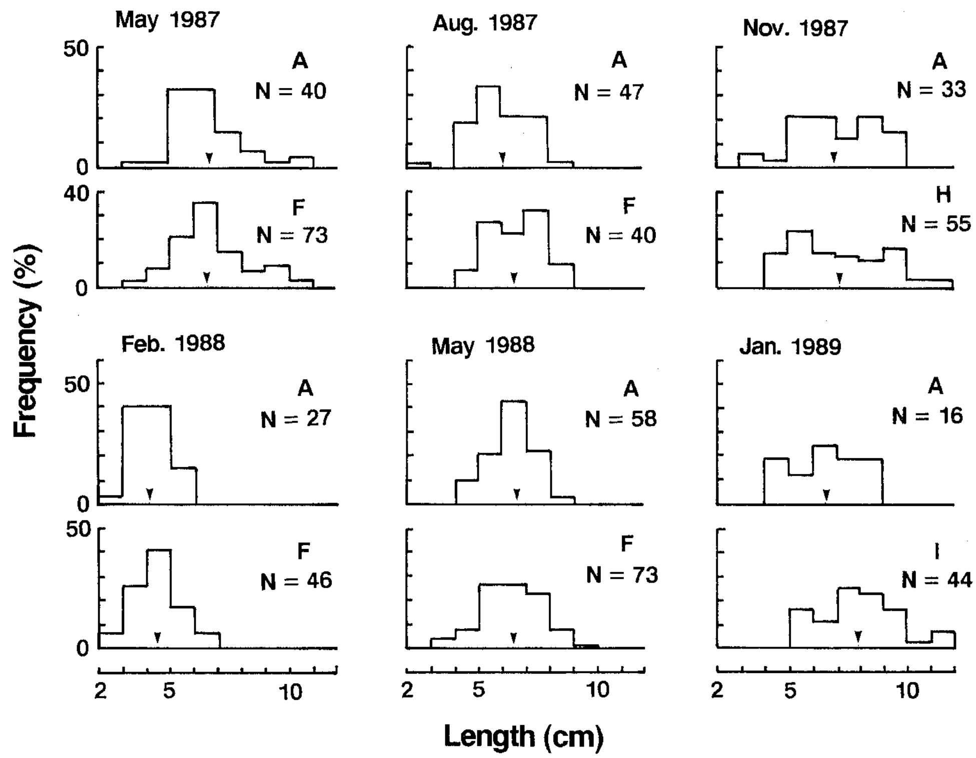

Fig. 4. Frequency distribution, as percentages, of body lengths of *Polycheira rufescens* from the highest sampling site (A) and the lower site (F, H, or I) where most individuals were collected. Sample means are indicated by arrowheads.

Table 3. Comparison of mean body lengths (cm) of *Polycheira rufescens* found under boulders of 10–20 cm length and those above 20 cm length at sampling sites where not less than 44 individuals were collected at each survey. SD: standard deviation, N: not significant.

	Site	10–20 cm		20 cm<		t-test
		n	$\bar{x}\pm$SD	n	$\bar{x}\pm$SD	
1987 May	F	29	6.76±1.65	46	6.38±1.50	N
	G	34	6.37±1.47	24	6.15±1.67	N
Aug.	A	12	7.12±2.99	33	5.79±1.08	$P<0.05$
Nov.	H	8	7.81±2.22	47	6.97±2.00	N
1988 Feb.	F	8	4.03±1.19	38	4.88±2.06	N
May	F	11	6.91±0.80	62	6.29±1.30	N
1989 Jan.	I	12	7.62±1.56	32	8.01±1.64	N

nov (1987) found in *Holothuria parvula* that the proportion of individuals showing transverse fission varied from 43 to 83% during a year. I encountered 3 individuals of *P. rufescens* whose bodies were about to separate transversely. The third possible reason could be seasonal visceral atrophy, which has been observed in other holothurians such as *Stichopus japonicus* by Choe (1963) and *Parastichopus californicus* by Fankboner & Cameron (1985). *S. japonicus* is reported to lose 33–40% of body weight (Choe, 1963) and *P. californicus* to lose over 25% of body wall weight (Fankboner & Cameron, 1985) during their atrophy season. At present, however, there is no evidence that suggests a direct relation between the sudden fall of the size peak and any one of the above three possible reasons.

Fig. 4 compares size structures between the highest site (A) and the lower site (below 60 cm above datum line) from which most individuals were collected. Histograms for the two sites generally resemble each other. Nishihira *et al.* (1978) noted in Okinawa that the smaller individuals of *P. rufescens* do not occur at the higher levels of distribution. However, at the present study sites, such a tendency cannot be clearly recognized from Fig. 4.

Table 3 compares body lengths of individuals occurring under the boulders of 10–20 cm length and those above 20 cm length at sampling sites from which not less than 44 individuals were collected at each survey. The body sizes are not significantly different between the two size classes of boulders, except at site A in August 1987 where individuals under small boulders are significantly larger than those under large boulders.

Thus, it appears that there is no relationship, in general, between body size of *P. rufescens* and distribution in relation to intertidal height and boulder size.

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